Prospects and requirements for measurement of the distribution of the elements with XEUS

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SRON

Overview

- General considerations
- Coronal abundances
- Clusters of Galaxies
- The WHIM
- Active Galactic Nuclei
- Conclusions

General considerations

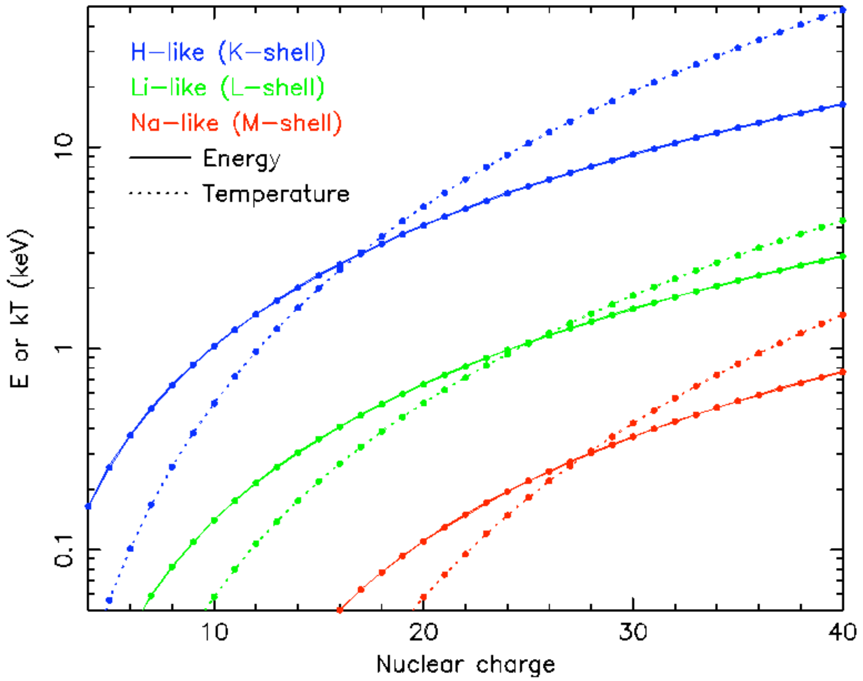
- In order to detect any emission/absorption line (equivalent width *EW*) with signal to noise ratio *S* and spectral resolution *_E* one needs at least N_l line counts with:

$$N_l > S^2(1+\_E/EW)$$

Conclusion: optimal resolution if _E<EW of measured line

Temperature sensitivity

- Determining abundances depends on plasma (T) structure; for each element, different ions for different T-ranges



Rare elements

K-shell

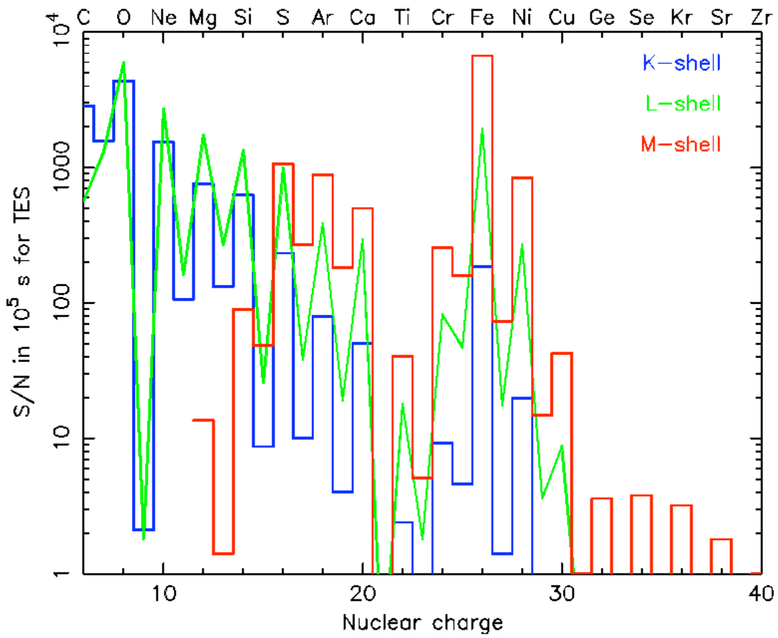
- Plots: maximum EW (as function of T) of lines for CIE plasma; solar abundances
- Lines with low EW need good:

1. Eff. area calibration
2. plasma diagnostics
3. atomic physics
4. bright sources

L-shell

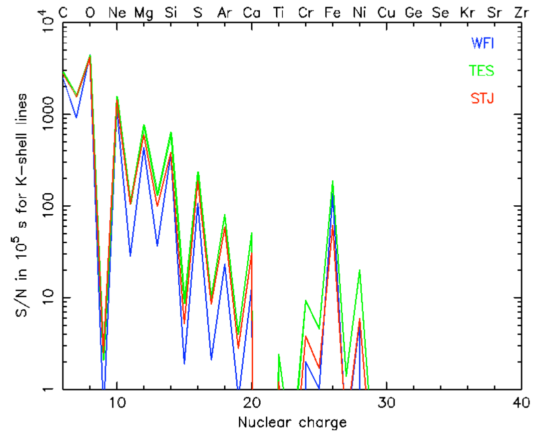
Coronal abundances

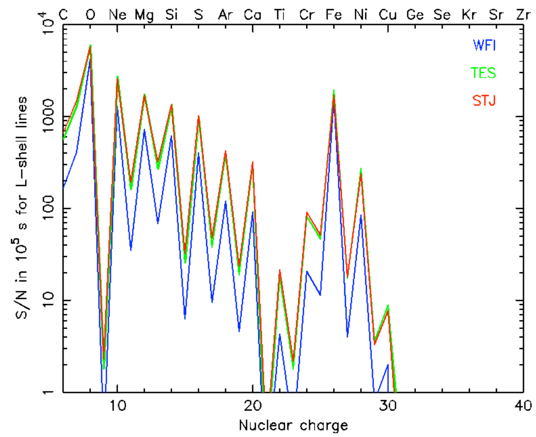
- Plot for CIE plasma with emission measure 6×10^{59} m^{-3} at d=50 pc (as in AR Lac)
- S/N calculated for T at peak line emission
- Shown are results for 10^5 s with TES



Comparison between instruments

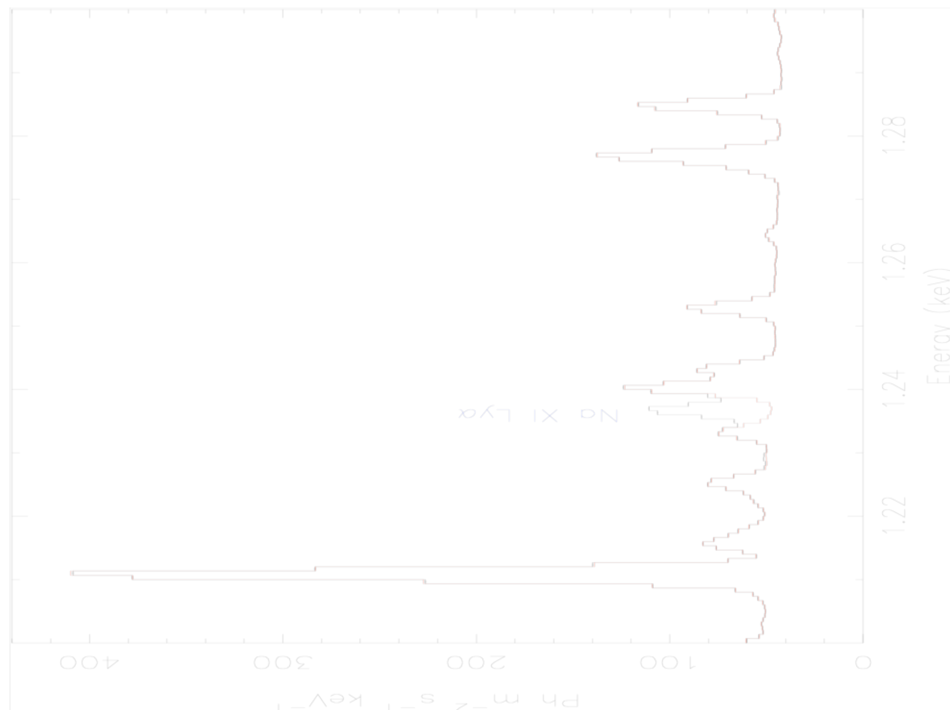
- Abundant elements (like Fe) do not require high resolution (in bright sources)
- Rare elements (like Na, Al, P) better seen with high resolution





Example: Na in coronal spectrum

- Needs to find weak lines in crowded spectral area
- High spectral resolution not only required for sensitivity but also for de-blending

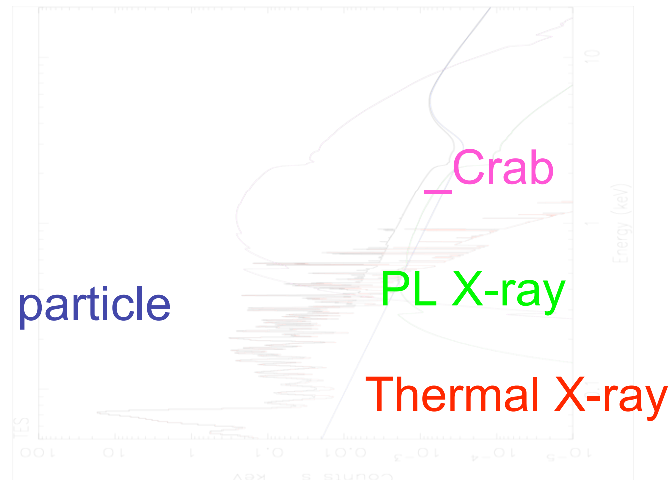


Effective area and spectral resolution

- _E and area from XEUS SRD draft
- Abundance determination: needs both high resolution (seeing the lines) and area (getting the photons)

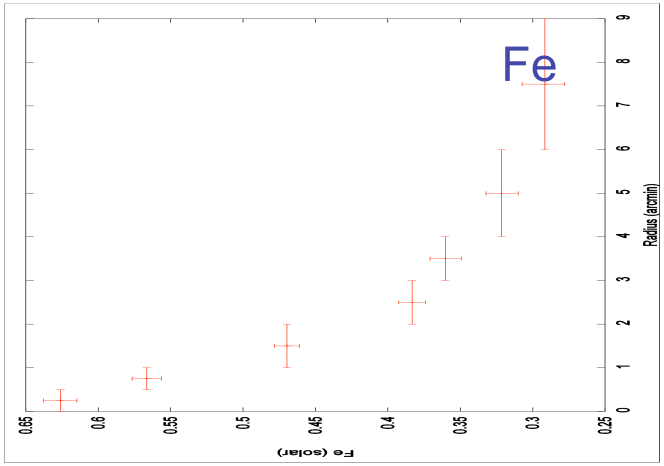
Background limitations for weak sources

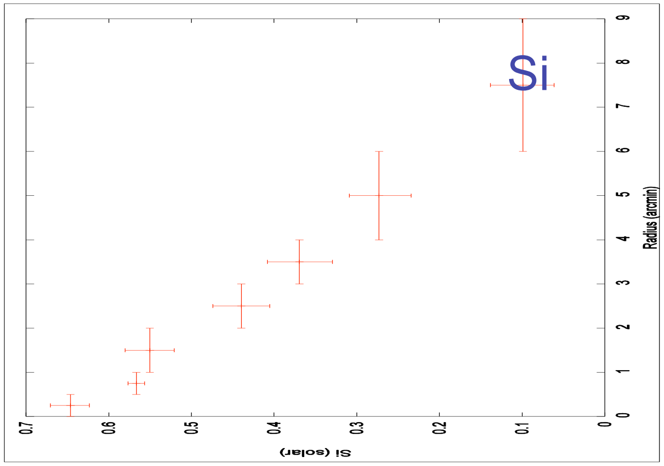
Background is of serious concern for weak sources: both at Fe-K and at low E



Clusters of galaxies: XMM

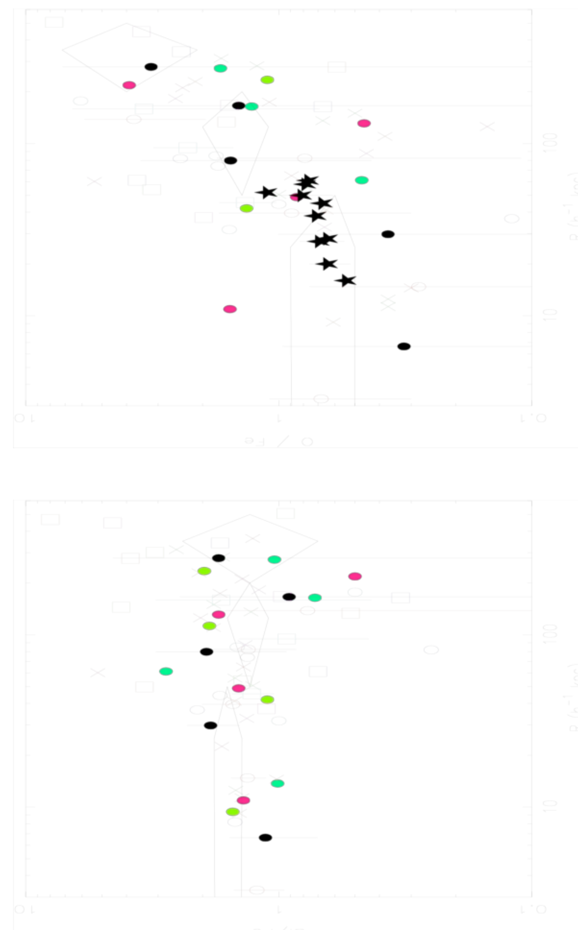
- Example: 130 ks of 2A 0335+096 with XMM-Newton
- Allows to determine radial profiles for Fe, Si, S, …





Radial distribution

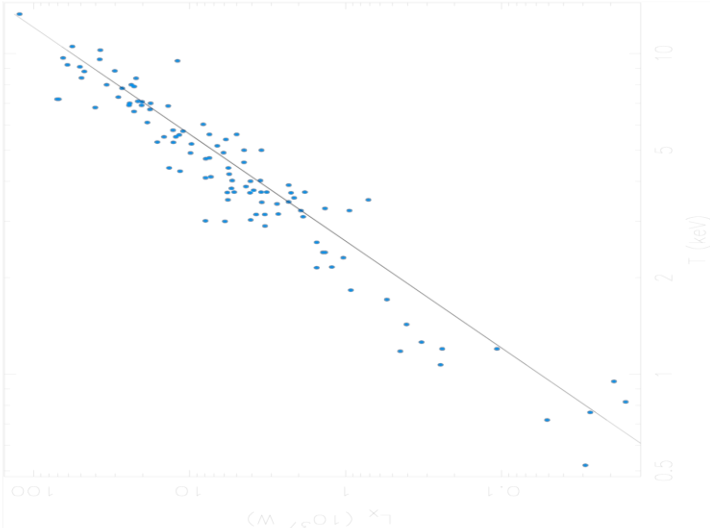
- Different behaviour of O/Fe and Si/Fe in clusters; what evolution?
- Different history type Ia and type II SNe
- Fe “inert” i.e. diffusion scale is small

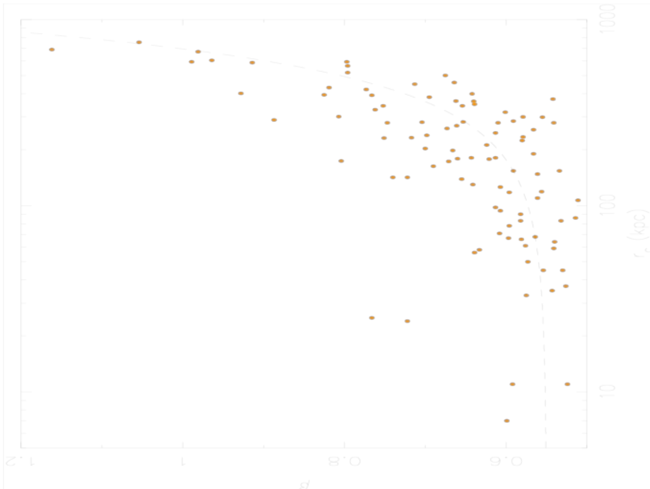


Tamura et al. 2003

Modeling of clusters

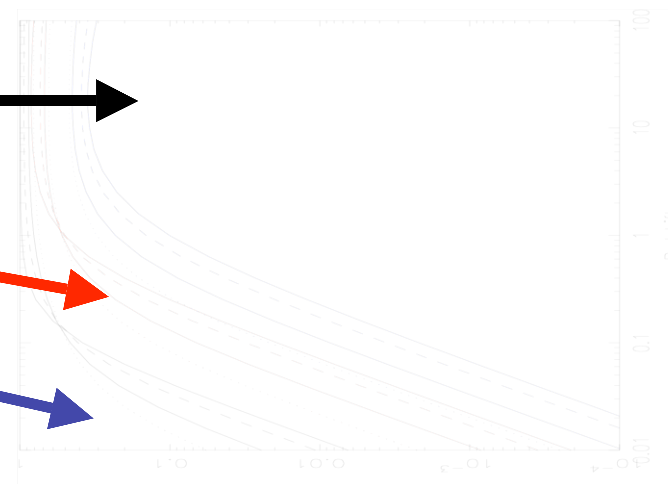
- Use scaling laws (here based on Reiprich & Böhringer 2002)
- Use simple evolution, for fixed T:
- $r_c \sim (1+z)^{-5/6}$
- $L \sim (1+z)^{1.5}$
- $M_{gas} \sim (1+z)^{-0.5}$



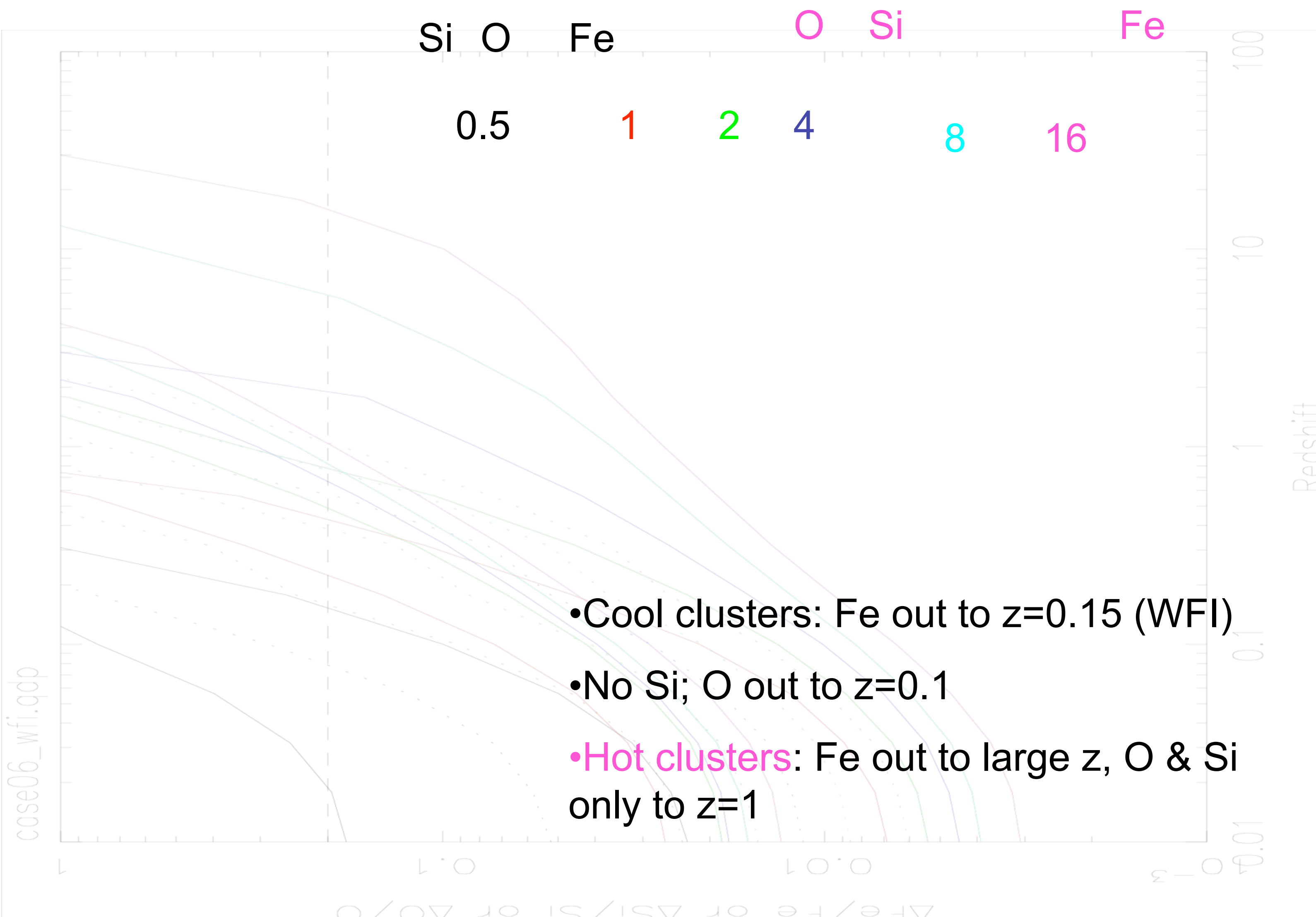


Sizes and apertures

- Angular size core radius ~constant for large z
- Enclosed energy fraction depends on aperture size:
- WFI 2.5 arcmin
- TES 0.45 arcmin
- STJ 0.15 arcmin



Abundances of Fe, Si, O in clusters

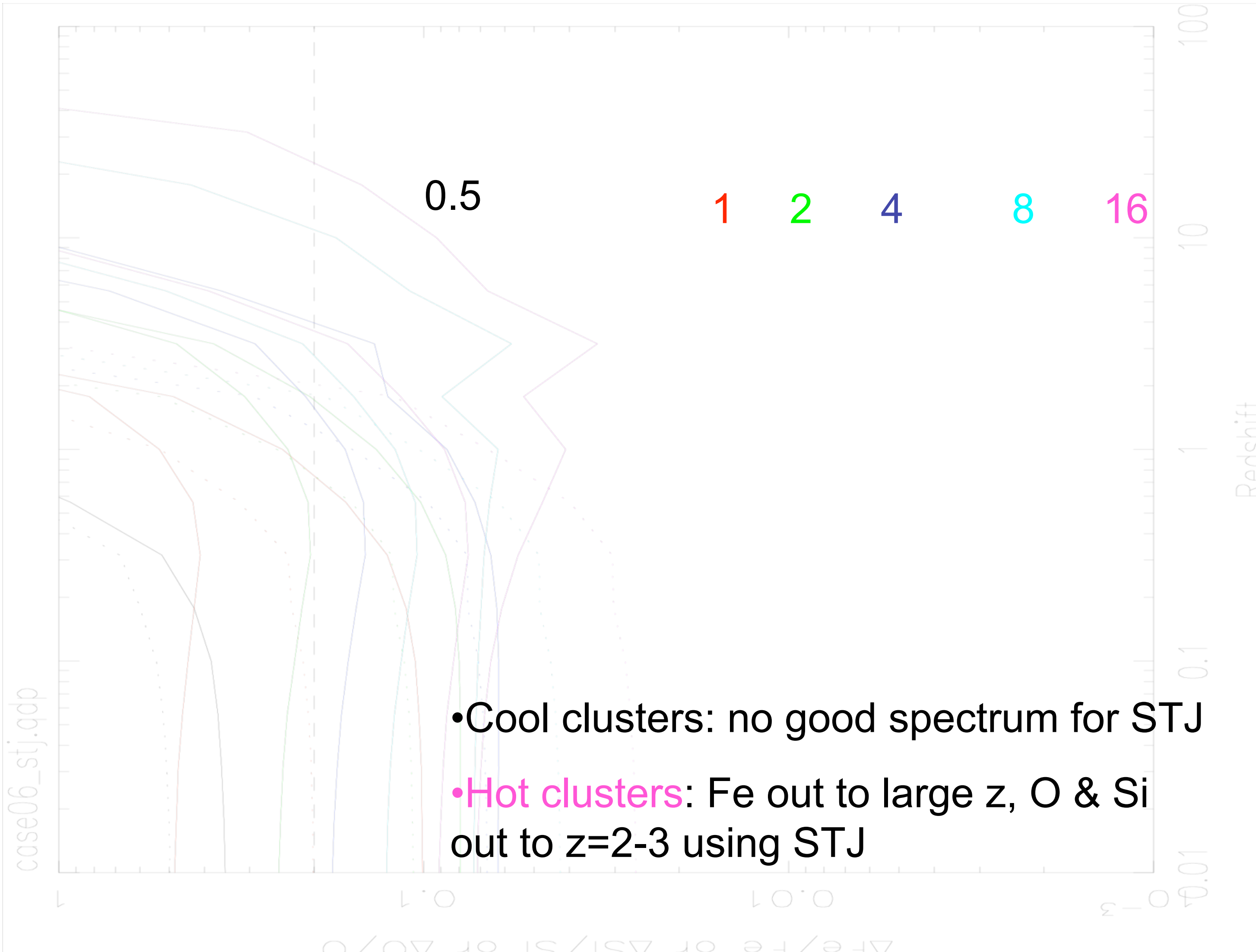


•Cool clusters: Fe out to z=0.15 (WFI)

•No Si; O out to z=0.1

•Hot clusters: Fe out to large z, O & Si only to z=1

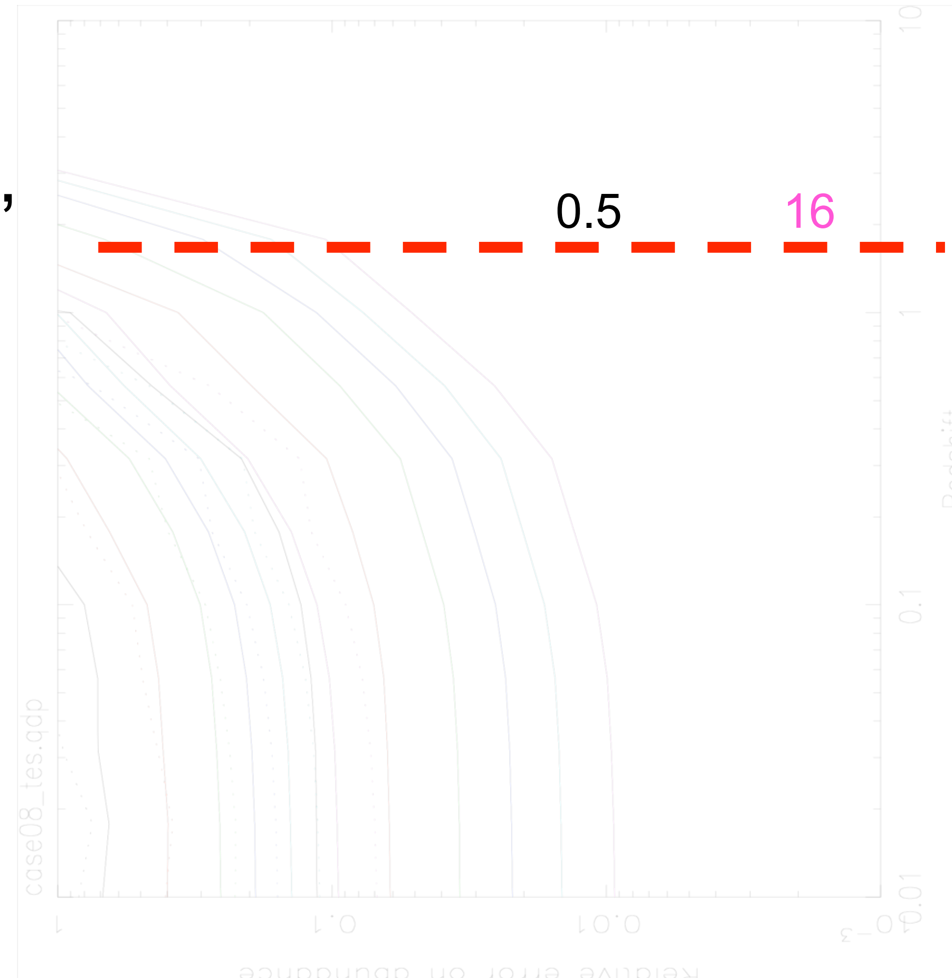
Abundances of Fe, Si, O in clusters



- Cool clusters: no good spectrum for STJ
- Hot clusters: Fe out to large z, O & Si out to z=2-3 using STJ

The CNO elements in clusters

- CNO best done using TES (STJ small FOV), WFI poor resolution (C,N lines only 1% above continuum)
- O (thick solid)
- N (thin solid)
- C (dotted)

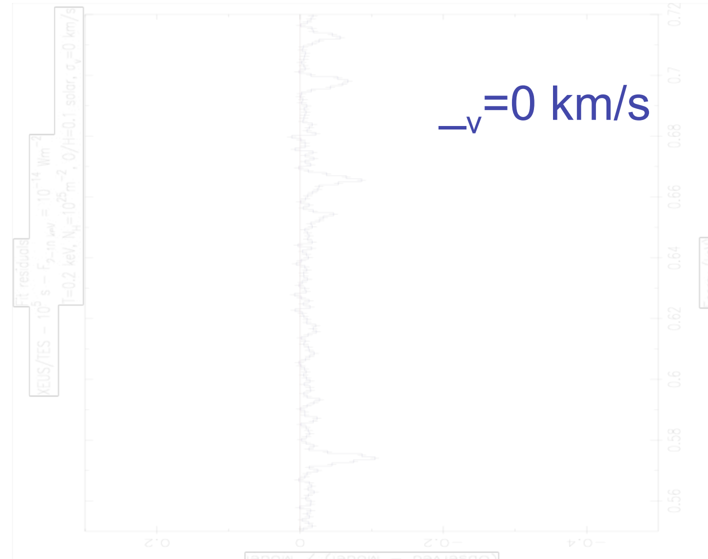


Rare elements in clusters

- Example: Na (dashed) and Al (solid)
- Hard to detect, out to z~0.3 for hot clusters with TES
- Impossible with STJ (field of view) or WFI (spectral resolution)

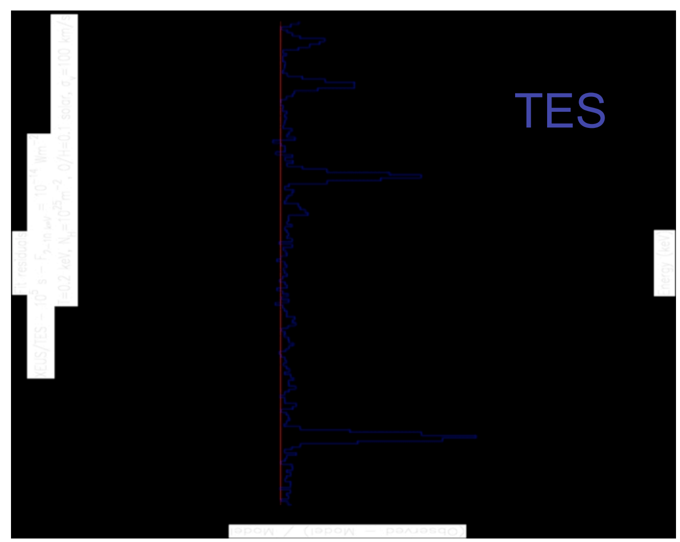
WHIM: narrow absorption lines

- Simulations for source with 2-10 keV flux of 10^{-14} W/m^2
- $N_H=10^{25}$ m^{-2}
- O/H = 0.1 solar
- kT=0.2 keV
- _v important



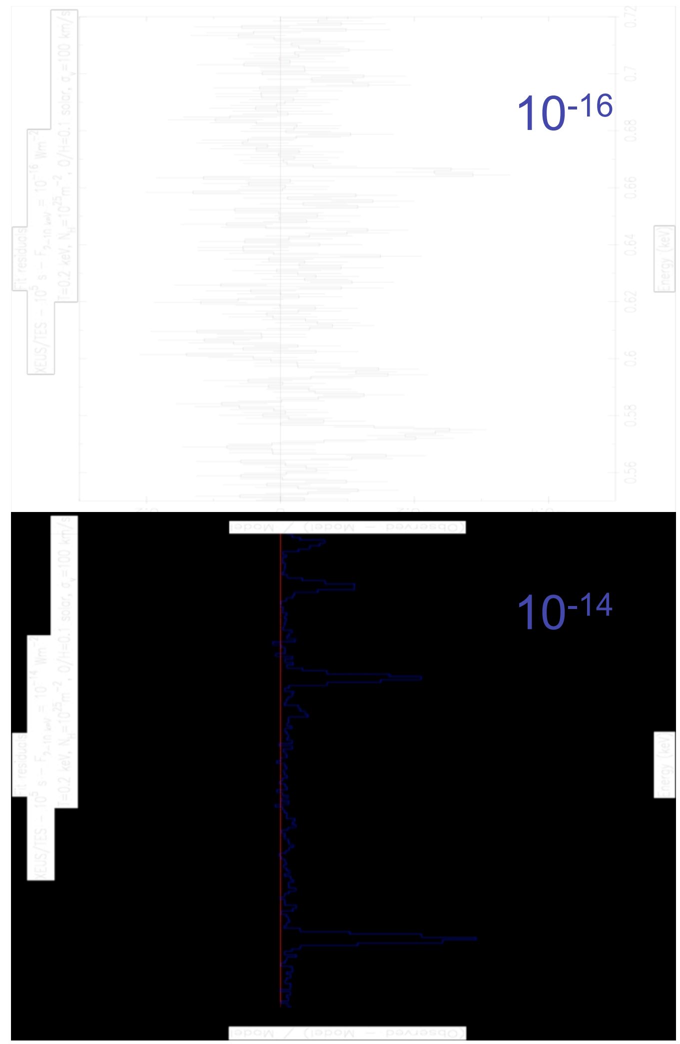
WHIM absorption: spectral resolution

- Simulations for source with 2-10 keV flux of 10^{-14} W/m^2
- $N_H = 10^{25}$ m^{-2}
- O/H = 0.1 solar
- kT=0.2 keV
- $\_{v}$ = 100 km/s
- spectral resolution important



WHIM absorption: sensitivity

- Simulations for source with 2-10 keV flux of 10^{-16} or 10^{-14} W/m^2
- There are 11 sources per _º >10^{-16} W/m^2 ideal for mapping
- Further as before
- need both large area & high res.



WHIM absorption: final remarks

- Absolute abundances (wrt H) extremely hard to get unless also Ly_ etc. measurements available
- Also relative abundances hard to get: needs to determine T, $\_{v}$ simultaneously with abundances

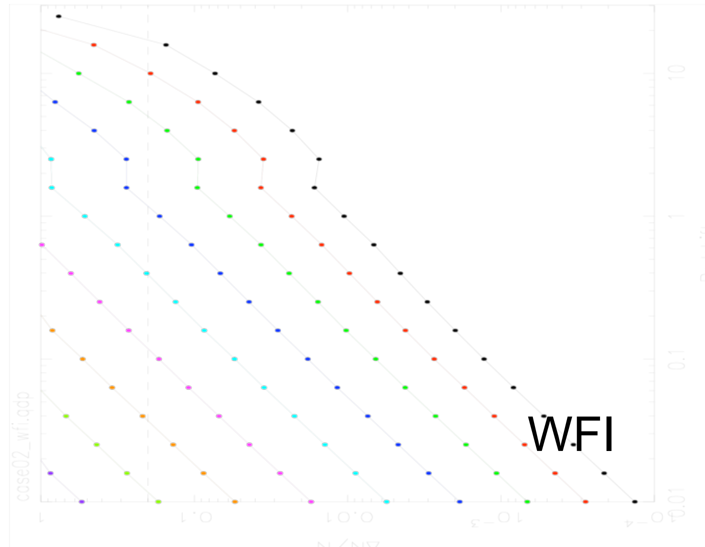
Using Fe-K emission lines in AGN as abundance tracers

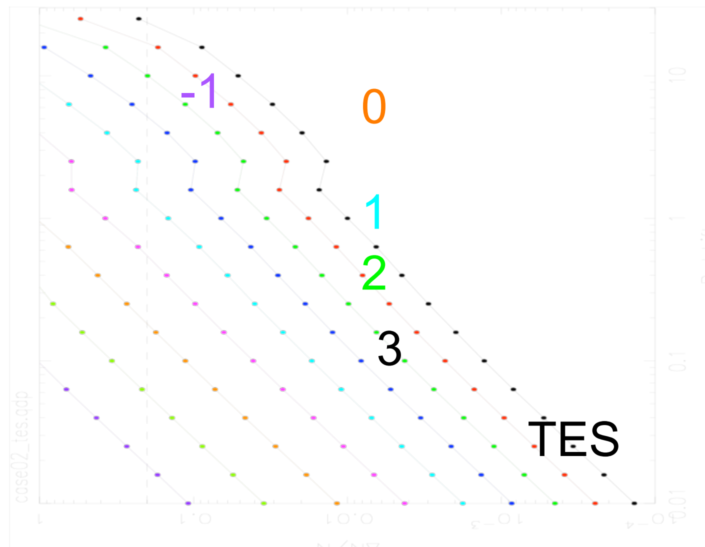
- Fe-K can serve as abundance tracer
- Both narrow and broad lines can be used
- But be aware of model-dependent effects:

1. Jet synchrotron emission
2. Accretion disk modeling
3. Narrow/Broad line region modeling

Detecting a narrow Fe-K line

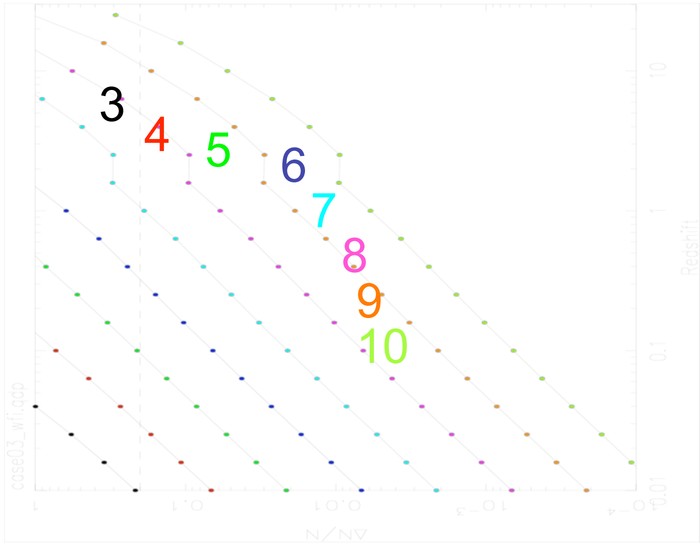
- Simulation for 10^8 Msun source at L_{EDD} (2.5×10^{38} W in 2-10 keV band)
- Lines with log EW (eV) between -1 and 3
- high resolution allows detection out to larger z

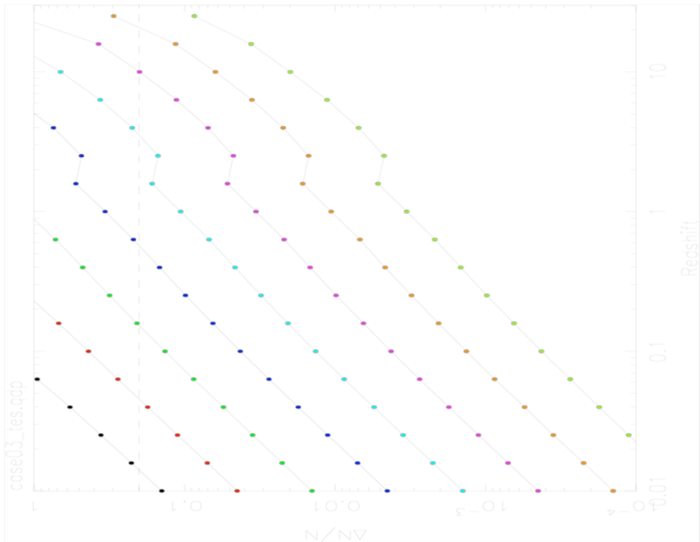




Narrow lines for different L

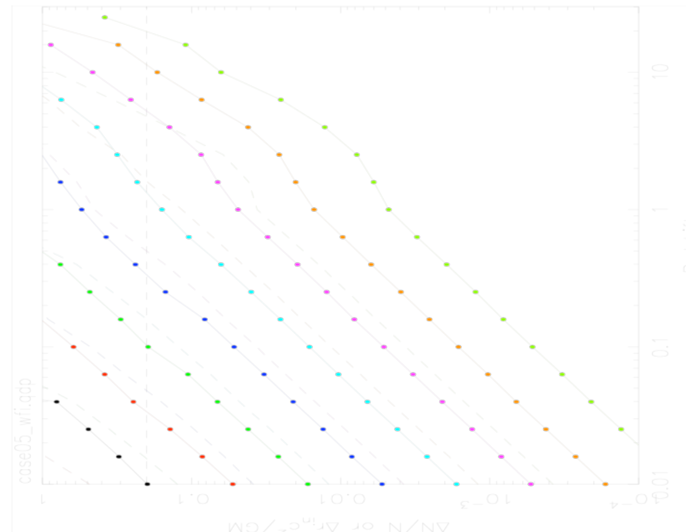
- Take a narrow line with EW = 100 eV
- Simulations for BH mass of 10^3-10^{10} Msun

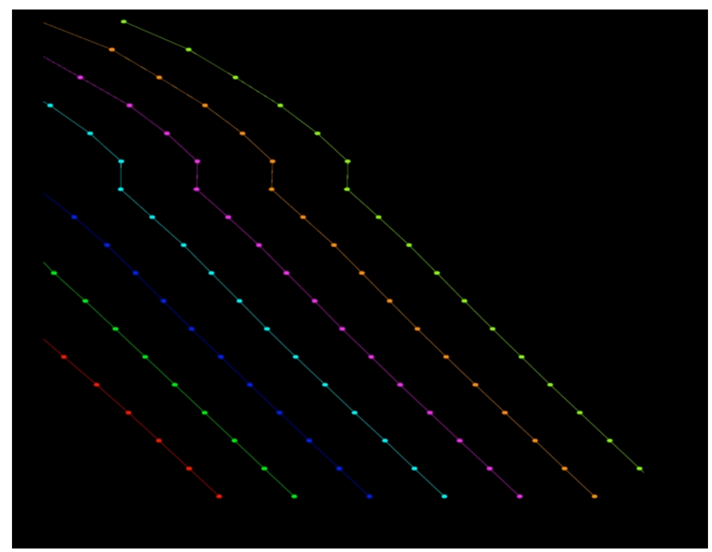




Detecting broad Fe-K lines

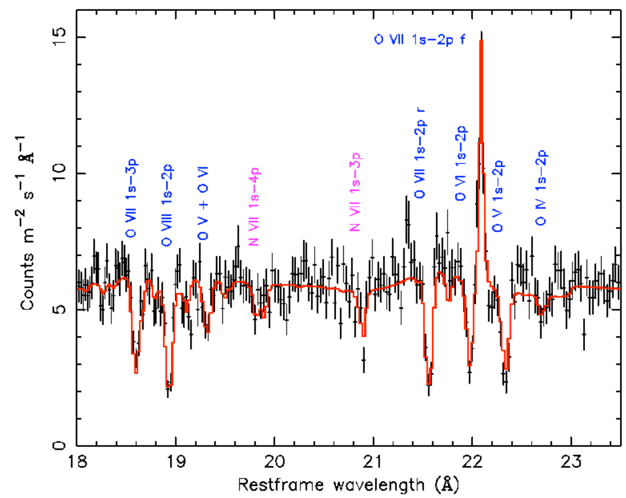
- Broad Fe-K lines (above) similar to narrow Fe-K lines (below), for WFI

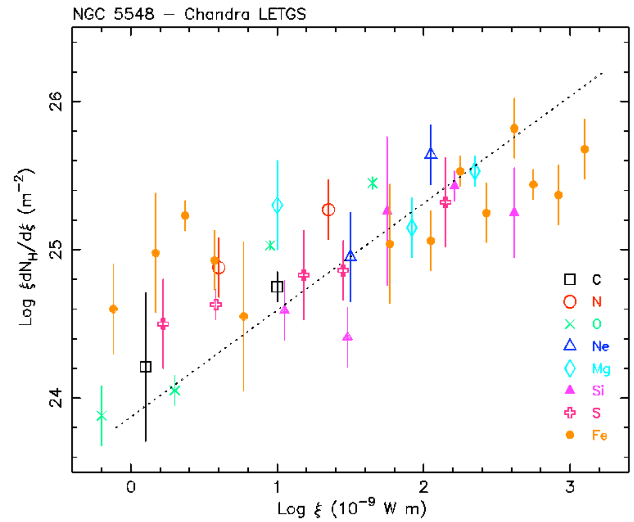




Using warm absorbers as abundance tracers

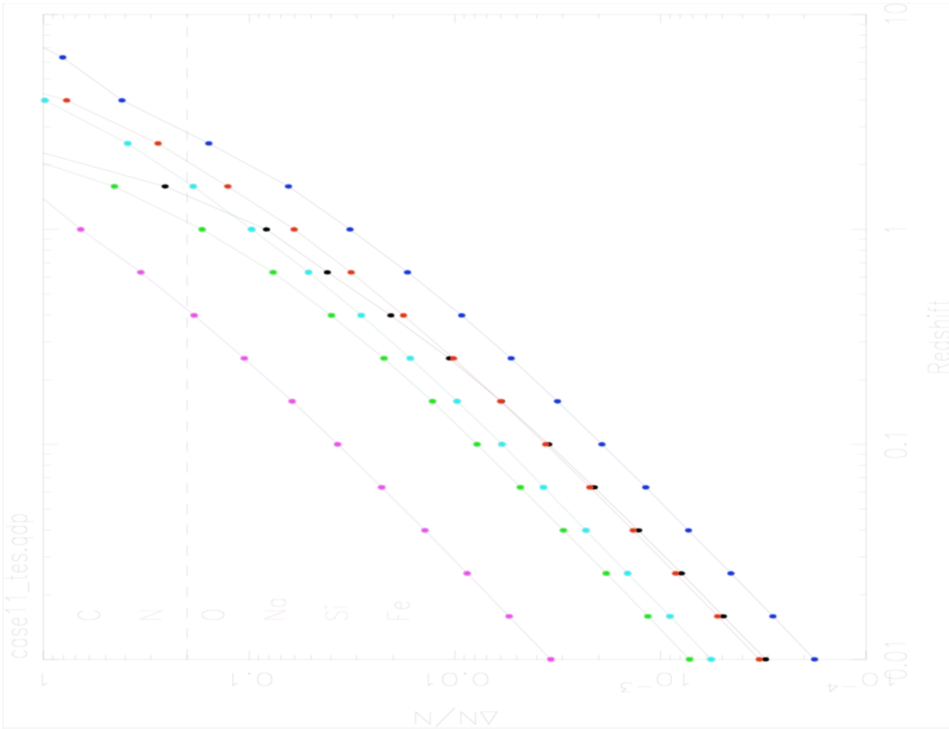
- About 50 % of Seyferts have warm absorber
- Many ions available, not just Fe





Feasibility of abundance measurements in warm absorbers

- Power law for 10^8 Msun source at L_{EDD} (2.5×10^{38} W in 2-10 keV band)
- Warm absorber as in NGC 5548
- Abundances of many elements out to z=1
- Improves for higher spectral resolution



X-ray background

- X-ray background rich in structure
- Affects all observations of dim sources (in particular extended sources)
- Need to understand it
- Useful for study of diffuse Galactic abundances

Grand summary of requirements for abundance studies

- In order to detect any emission/absorption line (equivalent width *EW*) with signal to noise ratio *S* and spectral resolution _*E* one needs at least N_l line counts with:

$$N_l > S^2(1+\_E/EW)$$

With here:

$$EW = (F_c + F_{back}) / F_l$$

Optimalization of instrument

- The following needs to be maximized:

	Extended	Point
Strong line EW>>_E	At_	At
Weak line EW<<_E	At_ / _E	At / _E

Conclusion

- For evolution studies of abundances, needs in particular at low E:
- high throughput (A),
- high spectral resolution (small _E, 1 eV or less)
- For extended sources, sufficient FOV (at least 1 arcmin size)